MECHANICAL PROPERTIES OF CALIFORNIA-GROWN MONTEREY PINE[1]

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MONTEREY PINE (*Pinus radiata* D. Don.) has become a softwood timber species of primary importance in many parts of the world. Because of its limited distribution and relatively small volume within its native range, however, it has not been well known nor highly regarded as a timber supplying species in California. One of the most rapid-growing California conifers, Monterey pine is well adapted to the coastal climate, and appears to flourish in a variety of soil types. It therefore seemed worthwhile to determine the mechanical properties of native-grown wood in order to assess its potentialities as a useful timber species in this state.

MATERIALS AND METHODS

Wood for testing was obtained from six trees. Four of them were growing in the center of the main stand of the species located on the Del Monte Properties between Monterey and Carmel. All four were dominant, mature trees in the forest, with relatively full, flat-topped crowns. They ranged in age from 50 to 75 years, and were 92 to 110 feet tall. The other two trees were growing in a plantation in Round Top Regional Park, just east of the city of Oakland, at an elevation of about 1,700 feet. All trees were cut separately and at long enough intervals to permit prompt testing of the green specimens. General information on the specimens used in the study is given in table 1.

The logs were cut from the trees in accordance with the general procedure described in American Society for Testing Materials Designation D143–49. Four logs between 8½ and 9 feet long were obtained from tree number 4, from the Monterey Peninsula; one such log 8 to 12 feet above the stump was obtained from each of the other five. In each case the log was cut so that a node was approximately in the center. Since the internodes were about 3½ feet long, this provided a maximum of clear, knot-free wood in each half (4-foot portion) of the log (fig. 1).

Test specimen blanks were prepared from the logs by following closely the procedure set forth in A.S.T.M. Designation D143–49. The 2½ × 2½-inch test blanks were assembled into two composite bolts from each log. One bolt was tested immediately in the green condition; the other was carefully

stacked under a shed roof to air-dry. All of the green material was tested within a couple of weeks following the cutting of the tree. During that period, the green specimens were wrapped in damp cloths tightly covered with waterproof paper to prevent surface drying, and stored in a refrigerated room at 34° F.

All mechanical testing, specific gravity determination, and shrinkage measurements conformed for the most part to the aforementioned A.S.T.M. standard. The following deviations should be noted, however. The stress-strain curves, from which the values for stress at proportional limits in compression parallel to grain were obtained, were based on the deflection over the full 8-inch length of the specimens rather than the 6-inch length

TABLE 1

AGE AND SIZE OF CALIFORNIA-GROWN MONTEREY PINE TREES
AND LOCATION OF TEST LOGS IN TREES

Tree no.	Approx. age	D.B.H.*	Total height	Log location	
				Height, large end	Height, small end
	years	*inches*	*feet*	*feet*	*feet*
1..........................	..†	28.3	...†	10.0	19.0
2..........................	50	29.4	101	14.0	22.5
3..........................	77	30.3	110	8.0	17.0
4..........................	76	26.2	92	2.0	11.0
				11.0	20.5
				33.5	42.0
				58.0	66.5
5..........................	43	28.7	76‡	12.4	21.0
6..........................	43	24.5	69	13.7	22.2

* Diameter outside bark at 4.5 feet above ground.
† Tree number 1 was cut by California State Division of Forestry personnel subsequent to selection by author. Age and height data were not obtained.
‡ Top broken out.

prescribed. The specific gravity values, based on oven-dry weight and volume at 12 per cent moisture content, were determined by using volume calculated from the dimensions of the specimen rather than by immersion. The specific gravity based on green volume, however, was determined on the basis of volume calculated by immersion in water as prescribed.

RESULTS AND DISCUSSION

Basic data for the various mechanical and physical properties of the green wood are listed in table 2, and for the dry wood, in table 3.

Moisture content of the green wood averaged about 35 per cent for the heartwood and 125 per cent for the sapwood. The latter showed the widest fluctuation, the rather dense tree number 3 having around 90 per cent, whereas the two lighter plantation trees, numbers 5 and 6, had 145 per cent. The dry wood was tested at approximately 12 per cent moisture content, the actual values fluctuating between 10 and 14 per cent. Adjustment to 12 per cent was made with the U. S. Forest Products Laboratory exponential formula (1939)[3] using the intersection point 28.5 per cent employed by

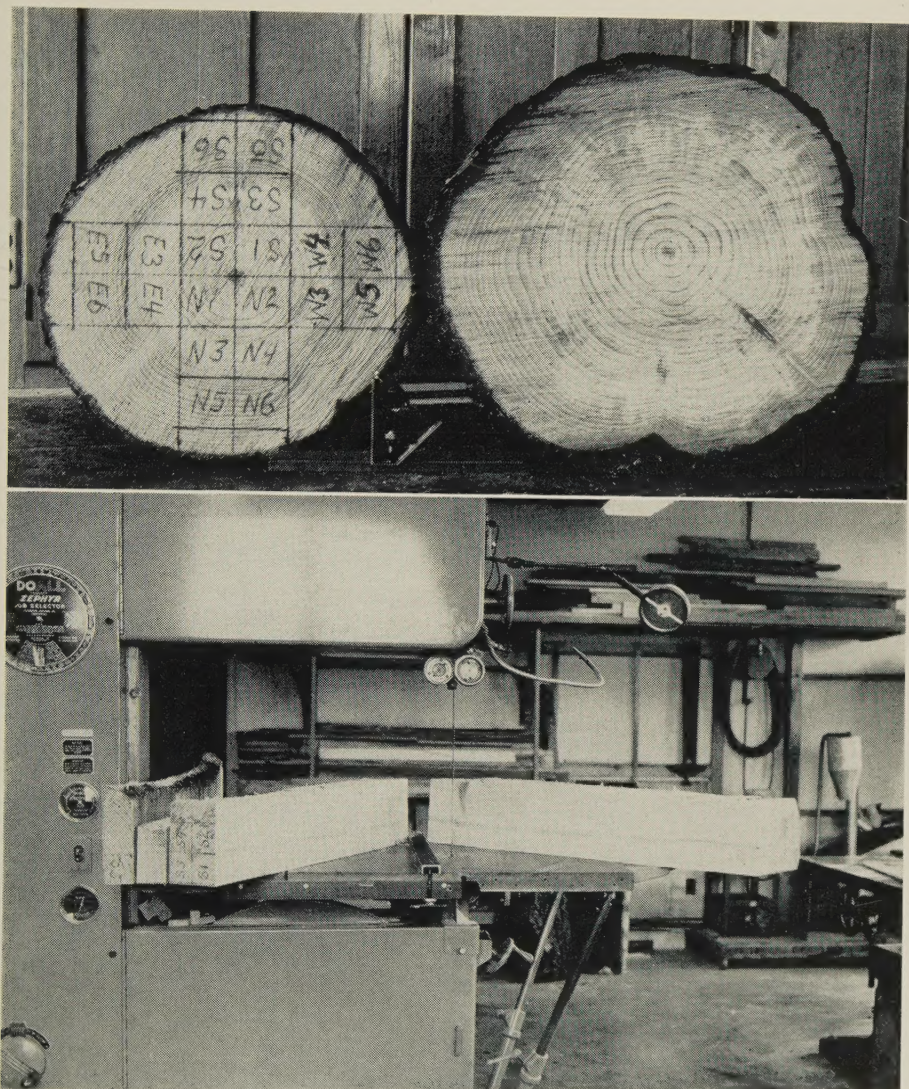[3] See "Literature Cited" for citations referred to in the text by author and date.

Fig. 1. Preparation of test specimens. Above: typical cross-sections of test logs. The log at left is marked for cutting. Below: test blanks $2\frac{1}{2} \times 2\frac{1}{2}$ inches, being prepared according to A.S.T.M. procedure.

Table 2

MECHANICAL PROPERTIES OF GREEN, CALIFORNIA-GROWN MONTEREY PINE (*PINUS RADIATA* D. DON)

Property	Tree number						Species mean	Standard deviation of tree means	Standard error of species means	Minimum individual test value	Maximum individual test value
	1	2	3	4	5	6					
Specific gravity:											
Volume green, weight oven-dry	(11)* 0.43	(12) 0.48	(15) 0.53	(32) 0.49	(8) 0.43	(6) 0.40	0.46	0.049	0.02	0.35	0.61
Volume oven-dry, weight oven-dry	0.49	0.54	0.61	0.56	0.47	0.44	0.52	0.063	0.026	0.39	0.72
Static bending:											
Fiber stress at proportional limit (p.s.i.)†	(14) 3,370	(10) 4,250	(13) 4,330	(35) 3,690	(9) 3,190	(8) 3,430	3,710	477	198	1,840	5,275
Modulus of rupture (p.s.i.)	5,970	7,130	7,940	6,970	5,810	5,930	6,625	858	350	4,400	9,000
Modulus of elasticity (1,000 p.s.i.)	1,400	1,450	1,780	1,610	1,170	1,100	1,420	258	105	585	2,090
Work to proportional limit (lbs. per cu. in.)	0.46	0.70	0.60	0.49	0.49	0.60	0.56	0.094	0.038	0.25	0.92
Work to maximum load (lbs. per cu. in.)	5.5	6.5	7.8	6.3	5.1	5.1	6.1	1.04	0.43	3.2	11.8
Total work (lbs. per cu. in.)	16.2	23.5	31.1	21.4	21.3	14.9	21.4	5.9	2.4	4.1	37.3
Impact bending:											
Fiber stress at proportional limit (p.s.i.)	(10) 10,920	(7) 12,000	(7) 11,590	(20) 11,120			11,410	484	242	8,430	14,030
Work to proportional limit (lbs. per cu. in.)	4.0	4.4	3.7	4.0			4.0	0.29	0.14	1.5	5.8
Height of drop causing complete failure (inches)	24.5	32.5	36.1	30.9			31.0	4.85	2.43	12.6	43.0
Compression parallel to grain:											
Stress at proportional limit (p.s.i.)	(19) 2,490	(15) 2,470	(23) 3,300	(50) 2,960	(12) 2,440	(10) 2,390	2,675	369	151	1,485	4,210
Maximum crushing strength (p.s.i.)	3,190	3,450	3,980	3,630	2,880	2,840	3,330	444	181	2,190	4,880
Compression perpendicular to grain:											
Stress at proportional limit (p.s.i.)	(13) 370	(6) 520	(9) 690	(29) 500	(6) 280	(6) 270	440	163	66	225	895
Hardness:											
Side (lbs.)	(14) 450	(6) 570	(9) 650	(28) 520	(5) 500	(6) 460	525	75	31	320	745
End (lbs.)	510	600	700	600	530	500	575	77	32	375	765
Maximum shearing strength parallel to grain (p.s.i.)	(18) 820	(18) 930	(20) 1,000	(51) 890	(12) 830	(12) 780	875	79	32	595	1,260
Cleavage (lbs. per in.)	(13) 220	(16) 250	(22) 290	(37) 230	(12) 230	(10) 220	240	25	10	160	445
Maximum tensile strength perpendicular to grain (p.s.i.)	(15) 360	(13) 430	(16) 410	(50) 380	(12) 400	(12) 350	390	30	12	270	580
Maximum tensile strength parallel to grain (p.s.i.)	(7) 12,810	(4) 11,580	(5) 13,790	(9) 16,840	(5) 11,050	(5) 8,310	12,400	2,866	1,170	7,410	19,340

* Numbers in parentheses refer to number of specimens tested for each property.
† Pounds per square inch.

TABLE 3

MECHANICAL PROPERTIES OF AIR-DRY, CALIFORNIA-GROWN MONTEREY PINE (*PINUS RADIATA* D. DON)

Property	Tree number 1	2	3	4	5	6	Species mean	Standard deviation of tree means	Standard error of species means	Minimum individual test value	Maximum individual test value
Specific gravity:											
Volume air-dry, weight oven-dry	(8)* 0.49	(11) 0.51	(11) 0.58	(32) 0.53	(11) 0.45	(6) 0.41	0.50	0.06	0.025	0.37	0.64
Volume oven-dry, weight oven-dry	0.53	0.54	0.63	0.56	0.48	0.44	0.53	0.07	0.027	0.38	0.69
Static bending:											
Fiber stress at proportional limit (p.s.i.)†	(16) 8,300	(10) 7,070	(12) 9,180	(33) 9,280	(13) 5,750	(7) 5,370	7,490	1,697	693	4,140	11,180
Modulus of rupture (p.s.i.)	13,410	14,200	16,270	15,170	10,180	10,120	13,225	2,566	1,047	7,550	18,850
Modulus of elasticity (1,000 p.s.i.)	1,820	1,710	2,280	2,130	1,330	1,470	1,800	323	143	840	2,820
Work to proportional limit (lbs. per cu. in.)	2.08	1.27	2.08	2.27	1.33	1.11	1.69	0.51	0.21	1.07	3.03
Work to maximum load (lbs. per cu. in.)	11.2	13.7	15.8	13.0	10.6	8.1	12.1	2.7	1.1	4.0	22.3
Total work (lbs. per cu. in.)	16.3	15.8	22.2	22.3	12.0	9.9	16.4	5.1	2.1	6.2	36.4
Impact bending:											
Fiber stress at proportional limit (p.s.i.)	(8) 14,460	(8) 14,630	(8) 17,980	(22) 17,850	......	......	16,230	1,947	974	8,670	23,240
Work to proportional limit (lbs. per cu. in.)	5.4	7.3	6.8	7.4	......	......	6.7	0.92	0.46	2.6	9.5
Height of drop causing complete failure (inches)	28.6	32.7	41.1	33.1	......	......	33.9	5.22	2.61	7.0	44.6
Compression parallel to grain:											
Stress at proportional limit (p.s.i.)	(18) 5,480	(19) 7,210	(21) 5,830	(57) 6,440	(14) 4,120	(9) 4,350	5,570	1,190	487	3,100	8,000
Maximum crushing strength (p.s.i.)	7,760	8,320	8,840	8,170	5,540	5,630	7,380	1,431	584	4,200	10,690
Compression perpendicular to grain:											
Stress at proportional limit (p.s.i.)	(8) 810	(8) 920	(8) 1,390	(27) 1,120	(7) 680	(5) 660	930	282	115	600	1,870
Hardness:											
Side (lbs.)	(8) 700	(8) 810	(8) 1,090	(30) 820	(6) 610	(5) 500	760	203	83	460	1,220
End (lbs.)	960	1,010	1,480	1,110	810	720	1,010	269	110	640	1,720
Maximum shearing strength parallel to grain (p.s.i.)	(17) 1,480	(17) 1,640	(18) 1,690	(42) 1,530	(6) 1,360	(14) 1,160	1,480	196	80	1,000	2,110
Cleavage (lbs. per in.)	(14) 235	(16) 228	(22) 300	(39) 270	(13) 260	(8) 250	255	26	10	140	430
Maximum tensile strength perpendicular to grain (p.s.i.)	(14) 400	(14) 500	(20) 500	(42) 435	(10) 480	(10) 410	455	45	18	300	660
Maximum tensile strength parallel to grain (p.s.i.)	(8) 18,150	(4) 22,030	(5) 23,080	(14) 19,830	(3) 14,530	(3) 9,590	17,970	2,629	1,073	10,200	30,850

* Numbers in parentheses refer to number of specimens tested for each property.
† Pounds per square inch.

Langlands in his study (1937). Actually, specimens from trees numbered 3, 5, and 6 were exactly 12 per cent when tested; trees 1 and 2, slightly above 12 per cent; and tree 4, slightly below. Since the number of tests made varied from tree to tree, the species mean was calculated from the tree means, rather than from the individual test values, so that each tree had equal weight. In this regard also, the writer was influenced by the statement made by Langlands (1937) that use of tree means in calculating the species mean gives a closer estimate of the true species mean than does use of individual tests.

Growth Rate. The growth rate of the material tested, as reflected by the number of rings per inch of radius, is indicated in table 4. These data are tabulated by test blank numbers, and are thus related to distance from the pith. Blanks 1 and 2 are immediately adjacent to the pith, and blanks 7 and 8 just under the bark. The data show that all the trees except number 1

TABLE 4

AVERAGE AND RANGE OF RINGS PER INCH FOR TREES TESTED

| Test blank nos.* | Tree 1 | Tree 2 | Tree 3 | Tree 4 | | | | Tree 5 | Tree 6 |
				Log 1	Log 2	Log 3	Log 4		
1 and 2	4½ (3–6)†	2 (2)	2 (2)	2½ (2–3)	3½ (3–4)	4 (3–5)	7 (6–8)	2 (2)	2 (2–3)
3 and 4	6 (4–7)	3 (2–4)	4 (3–8)	6 (4–8)	7 (6–8)	8 (6–12)	11 (9–13)	3 (2–4)	5 (3–6)
5 and 6	10 (5–16)	5 (3–8)	7 (5–13)	8 (5–12)	13 (6–18)	15 (13–19)	...	3 (2–4)	5 (3–7)
7 and 8	11 (9–14)	6 (5–7)	10 (5–18)	11 (10–13)	10 (8–11)	...	...	5 (3–8)	...

* Distances from pith within which ring count was made for blanks 1 and 2, 0 to 3.5 inches; 3 and 4, 2.5 to 5.6 inches; 5 and 6, 5 to 7.9 inches; 7 and 8, 7.5 to 10.3 inches.
† Numbers in parentheses represent minimum and maximum ring counts.

had very rapid growth in the material nearest the pith (boxed heart 5 inches square) in the lower part of the trunk. Trees numbered 2 and 5, however, had rapid growth wood appreciably beyond this pith zone, and all specimens of tree number 2 and most of those from tree number 5 were distinctly stronger than the specimens from near the pith that had approximately the same rapid growth rate.

Location in Log. Because the wide-ringed material near the pith appeared to be less dense and weaker than material farther from the pith, a comparison based on several selected properties was made between the specimens located within the 5 × 5-inch boxed heart (test specimens numbered 1 and 2 cut adjacent to pith) and all those located outside the boxed heart. These data are presented in table 5. With the exception of shearing and cleavage strengths, the strength values for the boxed-heart specimens are distinctly lower than for the specimens farther from the pith. This is consistent with studies of other investigators. For example, Markwardt and Wilson (1935) make the statement that, in coniferous species, wood near the pith is often of very rapid growth and low specific gravity. More recently, Larson (1957),

TABLE 5

COMPARISON OF STRENGTH OF MONTEREY PINE SPECIMENS ADJACENT TO PITH WITH THOSE FARTHER FROM PITH

Specimens	Specific gravity*	Modulus of rupture	Modulus of elasticity	Total work	Maximum crushing strength	Compression perpendicular to grain	End hardness	Side hardness	Shear	Cleavage
		p.s.i.†	1,000 p.s.i.	lbs.per cu. in.	p.s.i.	p.s.i.	lbs.	lbs.	p.s.i.	lbs. per in.
Tested in green condition:										
Adjacent to pith	0.41	5,610	1,020	15.6	2,710	390	490	430	830	210
Farther from pith	0.47	6,870	1,510	22.8	3,490	490	600	550	890	230

* Based on volume at test and oven-dry weight.
† Pounds per square inch.

TABLE 6

COMPARISON OF CALIFORNIA-GROWN MONTEREY PINE WITH SOME U.S. STRUCTURAL WOODS* AND AUSTRALIAN-GROWN MONTEREY PINE†

Sample	Specific gravity‡	Modulus of rupture	Modulus of elasticity	Total work	Maximum crushing strength	Compression perpendicular to grain	End hardness	Side hardness	Shear	Cleavage
		p.s.i.§	1,000 p.s.i.	lbs.per cu. in.	p.s.i.	p.s.i.	lbs.	lbs.	p.s.i.	lbs. per in.
Tested in green condition:										
California Monterey pine	0.46	6,620	1,420	21.4	3,330	440	570	530	875	240
Douglas fir (Pseudotsuga taxifolia)	0.45	7,600	1,550	19.2	3,890	510	510	480	930	160
Shortleaf pine (Pinus echinata)	0.46	7,300	1,390	26.1	3,430	440	410	440	850	200
White fir (Abies concolor)	0.35	5,700	1,030	11.4	2,710	370	380	330	750	170
Western hemlock (Tsuga heterophylla)	0.38	6,100	1,220	17.3	2,990	390	520	430	810	190
Redwood (Sequoia sempervirens)	0.38	7,500	1,180	15.2	4,200	520	570	410	800	170
Australian Monterey pine	0.41	5,770	1,100	19.0	2,650	395	450	425	630	200
Tested in air-dry condition:										
California Monterey pine	0.49	13,220	1,800	16.4	7,380	930	1,010	760	1,480	255
Douglas fir	0.48	11,700	1,920	22.9	7,420	910	760	670	1,140	180
Shortleaf pine	0.51	12,800	1,760	16.6	7,070	1,000	750	690	1,310	270
White fir	0.37	9,300	1,380	11.4	5,350	600	730	440	930	160
Western hemlock	0.42	10,100	1,490	15.3	6,210	680	940	580	1,170	200
Redwood	0.40	10,000	1,340	8.8	6,150	860	790	480	940	150
Australian Monterey pine	0.45	11,390	1,450	17.3	5,650	955	915	720	1,470	300

* Data for these species from U.S.D.A. Tech. Bul. 479.
† Data for Australian Monterey pine from C.S.I.R.O., Div. of Forest Products Tech. Paper No. 30.
‡ Based on volume at test and oven-dry weight.
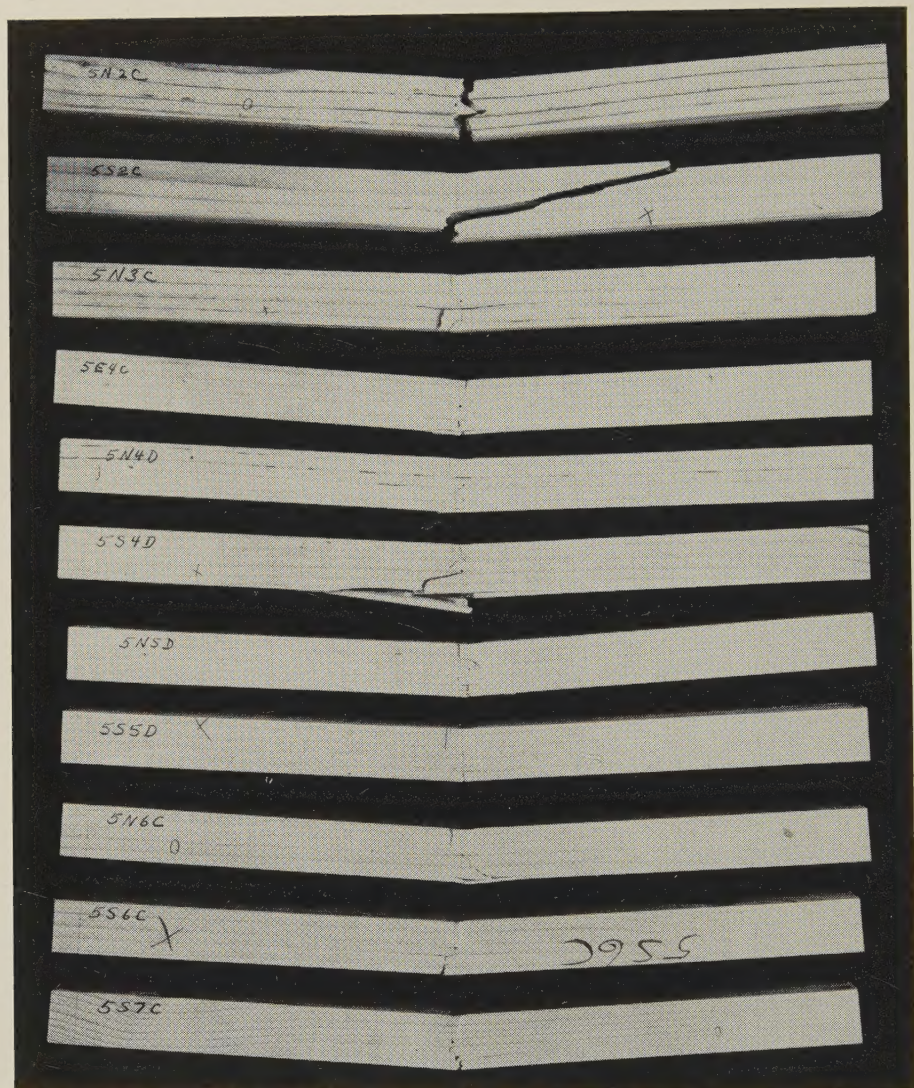§ Pounds per square inch.

Fig. 2. Samples from tree number 5, tested for static bending at 12 per cent moisture content.

in a study made on slash pine, concludes that "juvenile wood (up to 6 to 8 years) has been found to be inherently low in summerwood," and, in discussing his results, states that the juvenile wood produces poor quality lumber. He also points out that "rate of growth exerted a negligible influence on both specific gravity and percentage of summerwood and for all practical purposes its effect may be ignored." This same conclusion can be drawn from the high test values of the wide-ringed specimens (trees 2 and 5) outside the boxed heart.

Structural Qualities. Table 6 compares California Monterey pine with some of the structural woods more commonly used in the United States, and with Australian plantation-grown Monterey pine. The data show that California-grown Monterey pine compares very favorably with the structural softwoods commonly used in the United States. In most properties, it resembles both shortleaf and loblolly pine, which is not surprising since the Monterey pine is a hard pine with about the same specific gravity as the other two. As shown in tables 2 and 3, the dried wood, like that of the southern yellow pines, has a lower value for total work than does the green wood, whereas the dried Douglas fir wood (both coast and intermediate types, but not the Rocky Mountain type) shows a slightly higher total work value than the green wood. This suggests that hard pine wood in general tends to be less tough in the dry than in the green condition. The brittle rather than fibrous nature of the tension failure of the air-dry beams is illustrated in figure 2. Langlands (1938), in his study of Australian plantation-grown Monterey pine, reports that although *P. radiata* beams in the air-dry condition are characterized by a sudden "carroty" failure at ultimate load, they rank fairly high among other coniferous woods in ability to withstand shocks and blows. The test values reported in the present study, for impact bending for the four trees from the natural forest (see tables 2 and 3), corroborate Langlands' findings with respect to resistance to shock loads. When these values, for both the green and air-dry conditions, are compared with the impact bending values reported by Markwardt and Wilson (1935), they show Monterey pine wood to be distinctly superior to Douglas fir, slightly superior to loblolly and shortleaf pines, and essentially equal to longleaf and slash pines.

The strength values listed in table 6 for the Australian plantation-grown wood resemble very closely the comparable values for the California plantation-grown trees 5 and 6 (see tables 2 and 3), but are distinctly lower than strength values obtained for wood from the mature trees 1, 2, 3, and 4, grown in the natural forest. This agrees with the statement made by Olson *et al.* (1947), based on a study of six coniferous species that "... with few exceptions, the strength of forest-grown material is higher than that of plantation-grown woods." The writer would add, parenthetically, that the plantation-grown trees on which Olson's study was made were relatively young and small, and that forest-grown and plantation-grown trees of the same age and size might be expected to be essentially identical in their physical properties.

Another interesting comparison can be made between the strength of the boxed-heart specimens of this study (see table 5) and that of the Australian specimens. As might be expected, the strengths are similar since the average specific gravity of each class of material is identical. This fact explains the lower strength of the smaller and younger plantation-grown trees, since the

percentage of all the test specimens represented by the material near the pith
is greater in these smaller trees than in the larger and older trees grown in
the natural forest. These comparisons lead to the belief that the California-
and Australian-grown Monterey pines produce wood that is similar in
properties and that, for comparable density material, the test data and per-
formance record compiled in Australia can be applied to the California-
grown wood. Further study of a larger sample of California plantation-
grown trees is contemplated to test the validity of this belief.

The apparent superiority in strength properties of the old-growth trees
over the plantation trees suggested the possibility that there might be a
trend showing increasing strength with distance from pith at any given
level in the tree. Data for individual tests for all six trees were therefore ex-
amined. Disregarding the juvenile wood in the vicinity of the pith, no

TABLE 7

VARIATION OF STRENGTH WITH HEIGHT IN TREE NO. 4

Height above ground of bottom and top of test log	Specific gravity		Modulus of rupture (p.s.i.)*		Modulus of elasticity (1,000 p.s.i.)		Maximum crushing strength (p.s.i.)		End hardness (lbs.)	
	green	air-dry	green	air-dry	green	air-dry	green	air-dry	green	air-dry
ft.										
2–11..............	0.56	0.58	7,270	16,740	1,600	2,290	3,790	9,200	640	1,230
11–20.5..........	0.50	0.54	7,080	15,440	1,770	2,250	3,750	9,640	610	1,170
33.5–42..........	0.48	0.54	6,990	14,330	1,480	1,980	3,600	9,180	590	1,040
58–66.5..........	0.45	0.48	6,310	13,860	1,480	1,930	3,140	8,530	570	940

* Pounds per square inch.

evidence of trend was found in trees 1, 4, and 5, but trees 2, 3, and 6 did
show a slight tendency toward increase of density and strength outward
toward the bark. These results do not differ appreciably from the findings
of Langlands (1938) with regard to Australian-grown trees. It is not pos-
sible to compare these data closely, however, since Langlands' are based on
a series of $\frac{5}{8}$-inch-square specimens cut from radial boards, whereas the ob-
servations from the present study are based on the distance from the pith of
the various $2\frac{1}{2} \times 2\frac{1}{2}$-inch test blanks from all four cardinal directions (fig.
1, bottom).

To determine if density and strength vary with tree height, data for se-
lected properties from all logs of tree 4 were compared (table 7). The data
indicate rather consistently that density and strength decrease slightly with
increase in height. This is the same trend as that reported by Langlands
(1938) for his plantation trees.

Slope of Grain. Excessive slope of grain caused by spiral grain was not a
problem in any of the material tested except for a few specimens adjacent
to the pith, and even in these, only the material in the first and second rings
sloped appreciably. Slopes of grain from 1 inch in 8 to 1 inch in 10 were
recorded from several of the number 1 and number 2 specimens on the pith
sides, but on the outer side of these same specimens, all slopes of grain
measured were straighter than 1 inch in 16. The only other excessive slope
of grain was encountered on the ends of a few test blanks where proximity
to knots caused the grain to deviate. In a few instances, such slopes made
rejection of the material necessary (note specimens 5S6C and 5S7C in fig. 2).

Experience with other Monterey pine trees indicates that the slope of grain has about the same range as that of other commercial softwood species, particularly the southern yellow pines.

Shrinkage. Data on tangential, radial, and volumetric shrinkage are presented in table 8. They are of about the same general magnitude as those for many other structural softwoods of comparable density. Here again Monterey pine appears to resemble the southern yellow pines in having a some-

TABLE 8

SHRINKAGE PER CENT BASED ON
GREEN DIMENSIONS

Tree no.	Tangential		Radial		Volumetric	
	G–AD*	G–OD†	G–AD	G–OD		G–OD
1............................	...	...	...	...	....	11.8
2............................	4.8	7.5	3.5	5.3	....	11.9
3............................	4.6	7.6	3.9	6.5	....	13.1
4............................	4.1	7.0	3.4	6.1	....	12.5
5............................	4.1	6.3	2.3	3.8	....	10.2
6............................	4.4	6.6	2.5	4.1	....	9.1
Average.............	4.5	7.0	3.1	5.2	....	11.4
Australian‡.........	3.7	6.3	2.2	4.0	....	....

* Green to air-dry dimension.
† Green to oven-dry dimension.
‡ Data from C.S.I.R.O., Div. of Forest Products Technical Paper No. 28.

TABLE 9

A COMPARISON OF SPECIFIC GRAVITY AND CERTAIN BENDING
PROPERTIES BASED ON TWO 4-TREE SAMPLES OF GREEN
NATIVE-GROWN MONTEREY PINE

Tests	Specific gravity	Fiber stress at proportional limit	Modulus of rupture	Modulus of elasticity
		p.s.i.	*p.s.i.*	*1,000 p.s.i.*
Mould's*................................	0.49	3,660	6,980	1,487
Cockrell's................................	0.48	3,910	7,000	1,559

* See "Literature Cited."

what lower ratio of tangential to radial shrinkage than do some of the other common softwoods, such as white fir, hemlock, redwood, and spruce. This characteristic makes Monterey pine less likely to warp or distort with moisture-content change. Shrinkage data for Australian-grown material (Div. of Forest Products, 1939; Kelsey and Steele, 1956) indicate that, in this property also, Australian wood performs essentially the same as the native California material.

A study of density and some flexure properties of wood from four trees from the natural Monterey pine forest of California was reported by Moulds (1952). Table 9 shows a comparison of the species means for those four trees and the four from the same forest area used in this study. The closeness of the values strengthens the premise that data from this study are truly representative of native-grown Monterey pine wood.

SUMMARY

Average values for several basic mechanical and physical properties of both green and air-dried Monterey pine wood are reported as the result of tests made on six California-grown trees. These values demonstrate that native Monterey pine wood compares favorably in its mechanical properties with several important United States softwoods, especially the southern hard pines. It is also similar in its mechanical properties to Australian-grown Monterey pine wood. The wood of rapid growth near the pith was consistently lighter and weaker than that farther out in the cross-section, and generally had wider growth rings. Other than this weaker central core, there was no consistent general trend of strength with distance out in the cross-section from the pith. There was evidence, however, of a slight diminishing of strength with increasing tree height. Spiral grain was not a serious defect in the material tested except near the pith in a few specimens. The wood had shrinkage properties similar to other softwoods of comparable density.

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